

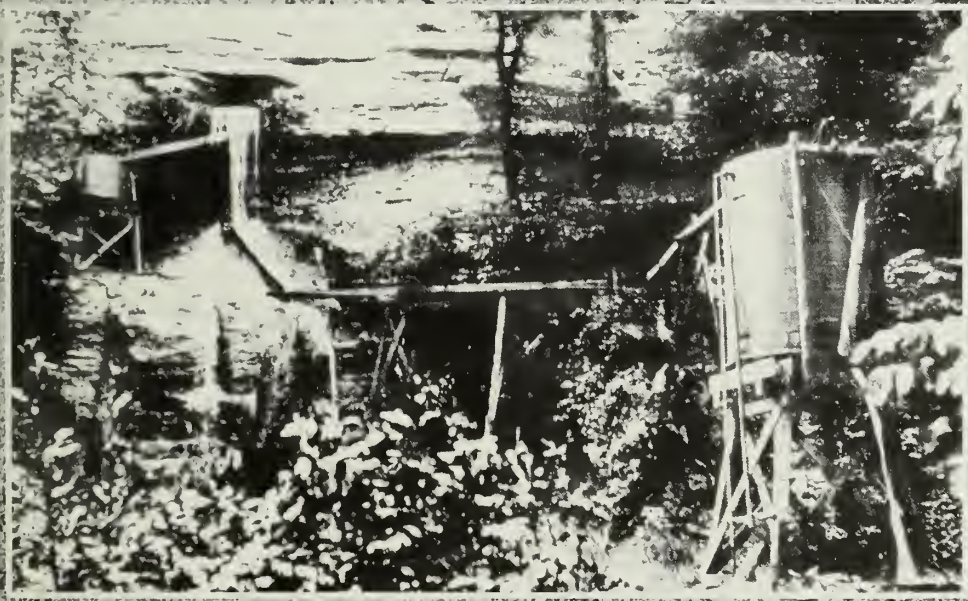
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Geology, Hydrology, and Water Quality of the Karst Regions of Southwestern Illinois and Southeastern Missouri

Geological Field Trip 2: April 24-25, 1999

Samuel V. Panno, C. Pius Weibel, Carol M. Wicks,
and James E. Vandike



ILLINOIS STATE GEOLOGICAL SURVEY
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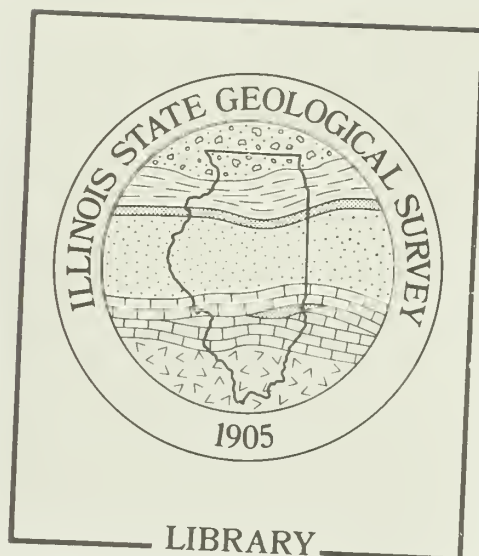
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Cover photo *Falling Spring, a small cave spring near Dupou, Illinois, is shown as it appeared in 1998 (main photo) and in 1900 (inset photo). The spring discharges from a bedding-plane cave in the St. Louis Limestone and was originally used as a water supply for domestic use and for steam locomotives (water towers). The water towers disappeared with the steam locomotive, and the spring now provides water for a nearby fishing pond.*

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INTRODUCTION

The broad belt of the sinkhole plains of southwestern Illinois and southeastern Missouri straddles the Mississippi River from roughly Cape Girardeau to north of St. Louis. As in most karst landscapes of the world, residents here confront sinkhole and water quality problems, sometimes on a daily basis. This field trip will acquaint participants with the geology, hydrogeology, groundwater geochemistry, and water quality of this karst terrain.

Geology

The karst terrain of southwestern Illinois and southeastern Missouri occurs primarily on Ordovician and Mississippian carbonate bedrock. The terrain generally developed on the uplands that rise 60 to 100 m on either side of the broad valley of the Mississippi River and its floodplain (fig. 1). Pleistocene glacial deposits are thin or absent in the area, although thick deposits of loess are present.

In southwestern Illinois, karst landscapes formed on Mississippian carbonate (mostly limestone) bedrock that subcrops beneath the Pleistocene deposits and is exposed in parts of St. Clair, Monroe, Randolph, and Jackson Counties. In Missouri, the karst landscapes formed on Ordovician and Mississippian carbonate bedrock in St. Louis, Jefferson, Ste. Genevieve, Perry, and Cape Girardeau Counties and in the city of St. Louis. The Ste. Genevieve Fault Zone traverses the karst terrain in Perry County (fig. 1) and separates Mississippian carbonates to the north and northeast from Ordovician carbonates to the south and southwest.

This band of shallow karst development extends from northeastern St. Louis County southeastward to Cape Girardeau County, a distance of about 180 km, and ranges from about 24 km to 35 km wide. North of this area, the terrain continues to Alton, Illinois, and to the Lincoln Hills (between the Mississippi and Illinois Rivers, just north of the area shown on figure 1).

Karst features are very common throughout this area, but intense karst development occurs in Missouri primarily in the city of St. Louis, extreme northeast and southeast St. Louis County, northeastern Ste. Genevieve County, and eastern Perry County, and in Illinois in west-central St. Clair County and western Monroe County (fig. 1).

This karst terrain of Illinois and Missouri broadly delineates the boundary between the Ozark Uplift to the southwest and the Illinois Basin to the east and northeast. The St. Francois Mountains, a subdued range of mountains about 120 km south-southwest of St. Louis, Missouri, forms the core of the Ozark Uplift. The deepest part of the Illinois Basin is in western Kentucky, more than 200 km to the southeast from St. Louis. Total structural relief in the Ozarks, where the Precambrian is exposed, is greater than 1.5 km, but the top of the Precambrian in the Illinois Basin lies more than 6 km below land surface (Bertagne and Liesing 1991). The average structural dip on the east and southeast sides of the Ozark Uplift is about 20 m/km; steeper dips are generally associated with faulting, local folds, or solution-induced collapse features. Major fault systems, such as the Ste. Genevieve Fault Zone (fig. 1), generally reflect the Precambrian basement structure and trend predominantly northwest and, to a lesser degree, northeast (Vineyard et al. 1981). The area has a long tectonic history, and, as a result of multiple tectonic deformation events (Kolata and Nelson 1991), jointing (fracturing without displacement) is very common in the bedrock.

Joints are important in the karstification process because they allow surface water and groundwater to move down into and through the bedrock, particularly the carbonate bedrock in the field trip area. In addition to water and joints, carbon dioxide is necessary for the formation of karst. As rainwater or snow melt seeps through the soil, carbon dioxide from the atmosphere and soil bacteria dissolves in the water to form relatively small amounts of carbonic acid, which reacts with and dissolves carbonate rock. Over tens to hundreds of thousands of years, this process has

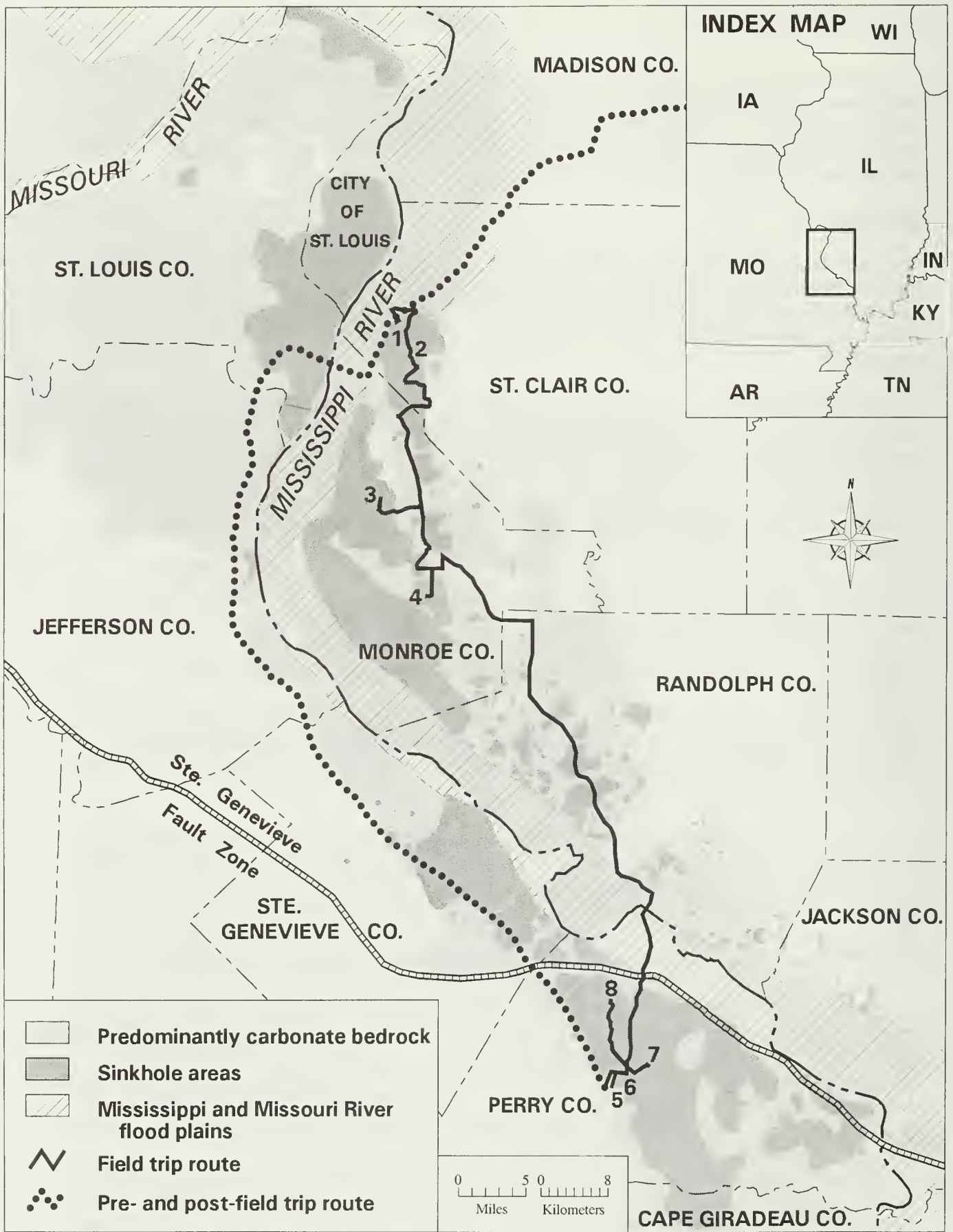
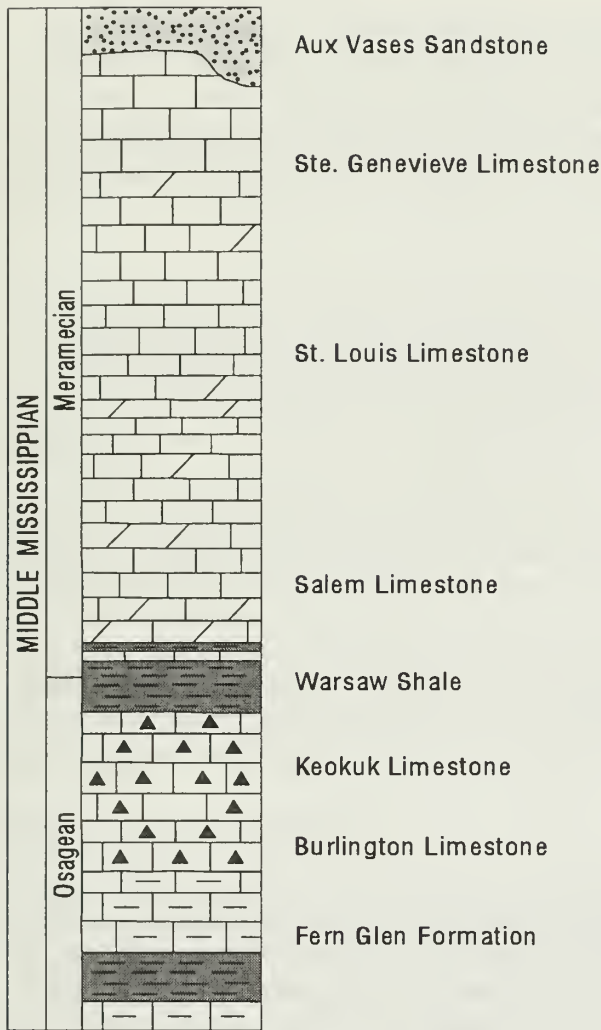


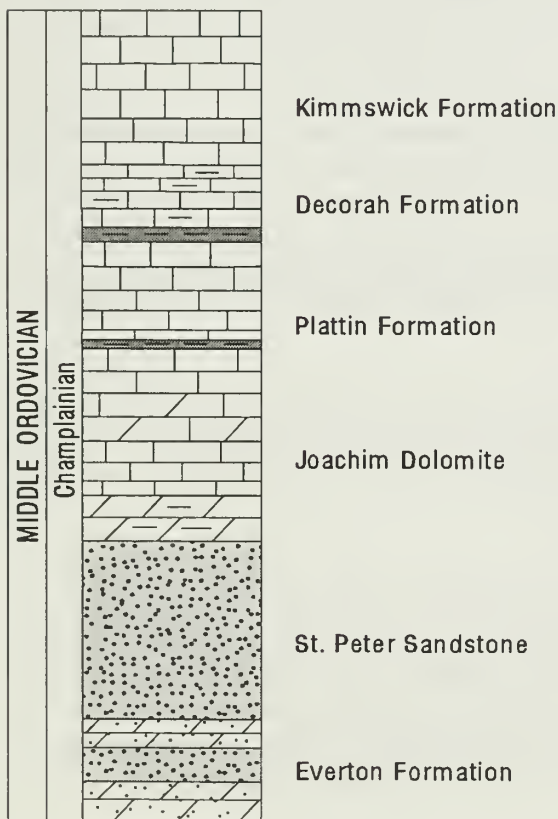
Figure 1 Location map showing field trip route, field trip stops, and generalized occurrences of predominantly carbonate bedrock, sinkhole areas, Mississippi and Missouri River flood plains, and Ste. Genevieve Fault Zone.



Aux Vases Sandstone dissolved significant volumes of carbonate rock as water migrated down vertical joints and along bedding plane partings. Over time, this process enlarges the joint openings at the bedrock surface and creates sinkholes in the overlying sediment.

Sinkholes are topographic depressions that characteristically form in landscapes with internal drainage (drainage that occurs underground within the bedrock instead of on land surface in streams). They are abundant in the karst terrains of Illinois and Missouri (fig. 1). These sinkholes typically are nearly circular in plan view and range in width from less than 1 m with a single drain into the bedrock, to nearly 1 km in diameter with multiple drains. Sinkholes act as natural drains for rainfall and snow melt and concentrate the large volume of water that flows rapidly into the underlying bedrock. Most groundwater in karst aquifers of this area ultimately flows through fissures and conduits that range from about 1 cm wide to more than 7 m in diameter.

Fissures and conduits drain a large percentage of the karst aquifer (Quinlan 1988). In addition to enlarging joint openings at the bedrock surface, dissolution enlarges the bedding plane partings to form horizontal conduits and caves. These conduits and caves provide lateral routes for the movement of the infiltrating water to springs, where it discharges. In many respects, the karst "plumbing" of sinkholes, conduits, and caves mimics manmade storm sewer systems.



Karst development can be found in nearly any of the many carbonate formations cropping out in both southwestern Illinois and in southeastern Missouri, but intense karst development is limited to specific stratigraphic units. Of near-surface bedrock units in southwestern Illinois, upper-middle Mississippian (Meramecian) strata (fig. 2) are most susceptible to karst development, particularly in west-central St. Clair and west-central Monroe Counties. Karst features occur more commonly in the St. Louis Limestone than in any other stratigraphic unit, but the underlying Salem Limestone and the overlying Ste. Genevieve Limestone (fig. 2) also contain many karst features. The longest caves in Illinois occur in the St. Louis Limestone

Figure 2 Generalized stratigraphic column of middle Ordovician and middle Mississippian strata in the field trip area (modified after Thacker and Satterfield 1977 and Weibel and Panno 1997; not to scale).

in Monroe and St. Clair Counties. In Missouri, intense karst development in northeastern and southeastern St. Louis County occurs primarily in the St. Louis Limestone. In eastern Ste. Genevieve County, the Ste. Genevieve Limestone hosts many sinkholes and caves. In eastern Perry County, the middle Ordovician (Champlanian) Joachim Dolomite and Plattin Formation (fig. 2) underlie extensive sinkhole plains and are host to hundreds of caves, including several of the longest caves in the United States.

Hydrogeology

Groundwater flow in shallow karst aquifers consists of both diffuse flow and conduit flow (White 1988). Groundwater flow systems can be divided into discrete groundwater basins, which are analogous to watersheds. Each basin consists of an area whose bedrock is rife with solution-enlarged fractures, bedding planes, and conduits; some conduits may be large enough to be caves that drain a specific recharge area. Groundwater is controlled, for the most part, by secondary permeability features, including near-vertical fractures, bedding-plane partings, and solution-enlarged crevices and conduits. Because of the abundance of sinkholes, recharge to shallow karst aquifers is rapid (often minutes to hours) as surface water enters solution-enlarged crevices and the conduit systems.

The karst terrains of Illinois and Missouri include numerous groundwater basins whose karst aquifers are open systems with water levels that are typically about 10 m below the soil-bedrock interface. The distal end of a groundwater basin is characterized by one or more springs that discharge to, and generally are the headwaters of, surface streams, which in this area ultimately discharge to the Mississippi River.

Water Quality

Groundwater in this karst terrain is a calcium-bicarbonate-type water and is particularly susceptible to contamination through the extensive honeycombed system of conduits in carbonate bedrock. Recharge to, and movement of water within, karst aquifers is often comparable to surface stream flow rates, and both entrained and dissolved contaminants are readily carried into the aquifer. Shallow groundwater in karst landscapes does not have the benefit of the slow filtering that is afforded to water infiltrating thick sequences of clay- and silt-rich glacial till or low-permeability bedrock in other landscapes.

Most of the springs in southwestern Illinois and probably southeastern Missouri are contaminated with bacteria and pesticides from agricultural activities, private septic systems, and natural sources (Panno et al. 1996). Unfortunately, little data on water quality in this part of Missouri are available. Contaminants from the land surface that are transported into shallow karst aquifers may include relatively high concentrations of nitrate, bacteria, and organic chemicals. Water quality data for the Perryville, Missouri, karst area are sparse. Limited data on major cations and anions in nine springs are reported by Vandike (1985a).

Because of the relatively high bacterial counts in most springs in the sinkhole plain, drinking spring water or allowing it to come in contact with an open wound is strongly discouraged. Visitors with compromised immune systems are discouraged from coming in contact with the water because of the presence of opportunistic pathogens.

Agrichemicals

Land use in the sinkhole plains of southwestern Illinois and southeastern Missouri is predominantly agricultural. Row crops grown in the area are dominantly soybeans and corn, but include milo, alfalfa, wheat, and barley. Atrazine and alachlor are the most common herbicides used in this area; other chemicals applied to the soils include anhydrous ammonia, potash, and phosphate (Panno et al. 1996). Livestock operations are generally small hog and cattle raising facilities.

The herbicides atrazine and alachlor and elevated concentrations of nitrate are routinely found in spring water in southwestern Illinois. The highest concentrations are present during the spring season immediately following field applications. Herbicide concentrations in springs range from 0.1 to 98 µg/L; nitrate (as nitrogen) concentrations typically range from 4 to 6 mg/L. Herbicides were found in as many as 55% of private wells sampled in April 1995 (Panno et al. 1996). Like that in the springs, the occurrence of herbicides in wells is also seasonal.

Nitrate concentrations in water from bedrock wells of southwestern Illinois ranged from less than 0.1 to 30 mg/L (as nitrogen). Elevated concentrations of nitrate (above background) and concentrations of nitrate exceeding the USEPA's MCL of 10 mg/L standard were found to occur in 17% and 10% of the wells, respectively (Panno et al., unpublished manuscript).

Garbage

Sinkholes have always been tempting sites for disposing of trash, household garbage, old appliances, dead animals, and disabled vehicles. These materials contain contaminants, such as oil, gasoline, bacteria, toxic chemicals from home cleaners and agricultural chemicals, that pollute the groundwater. For example, water pumped from a karst window near Illinois Caverns and used as water source for livestock was found to contain what appeared to be used motor oil (B. Schuckhardt, personal communication, 1993). In addition, large objects discarded into sinkholes can plug the sinkhole and alter the established drainage pattern. Localized flooding and/or accelerated erosion can result.

Private Septic Systems

Recent improvements to Monroe County infrastructure, primarily along Illinois Route 3, have led to a rapid increase in development and a rapid increase in the number of private septic systems. Septic systems in southwestern Illinois commonly drain directly into sinkholes and introduce septic effluent into the groundwater. Panno et al. (1997a, b) demonstrated that drainage probably from most of the private septic systems in Illinois' sinkhole plain exceeded state and local health codes for fecal coliform content. For example, the effluent from 63% of 19 professionally-maintained aeration-type septic systems in Monroe County did not meet state regulations for less than 400 colonies of fecal coliform/100 mL water. Ten percent of the septic systems in the county were actually cesspools (no treatment) with illegal overflows (Panno et al. 1997a). Such conditions introduce poorly treated to untreated human waste directly into the shallow karst aquifer. At least in part because of this practice, 55% of wells sampled in Monroe County in July 1995 tested positive for coliform bacteria (Panno et al. 1996).

KARST TERRAIN OF SOUTHWESTERN ILLINOIS

Road Log

Miles from start	Miles from last point	
0.0	0.0	Road log begins at Exit 13, I-255 South and IL-157, between Centerville and Dupo, St. Clair County, Illinois. Turn left (southeast) onto IL-157.
0.2	0.2	Turn right onto Triple Lakes Road.
0.5	0.3	Turn right onto Stolle Road.
0.9	0.4	Pass Stolle Quarry on left.

- | | | |
|-----|-----|--|
| 2.6 | 1.7 | Turn left onto McBride Avenue. Near the bluff, the road turns to the right and becomes LePere. |
| 3.8 | 1.2 | Turn left onto Falling Spring Road. |
| 3.9 | 0.1 | Enter Falling Spring Park. |
-

Stop 1: Falling Spring (Section 15, T1N, R10W, St. Clair County)

Falling Spring is a conduit spring and a waterfall that discharges from the steep limestone bluff (fig. 3) at the eastern edge of the Mississippi River Valley. Most of the bluff, including the strata within view, consists of St. Louis Limestone. The top of the bluff is capped by several meters of Ste. Genevieve Limestone, which are not visible from this vantage point (Z. Lasemi and R. Norby, personal communication, 1998). The spring discharges from a small cave opening, about 1 m high by 2 m wide, along a bedding plane about 11.5 m up from the base of this 50-meter bluff. This cave spring is typical of southwestern Illinois caves, which formed along bedding plane partings within limestone. Early explorers of this cave were able to follow the cave passage for several hundred meters without having to crawl (Bowman and Reeds 1907). Falling Spring is one of a few sites in this karst terrain that includes a scenic waterfall and a large deposit of tufa precipitated beneath the cave spring entrance. Tufa is a porous deposit of calcium carbonate that is associated with calcareous springs and seeps.

The spring was used as a source of fresh water. Among other uses, early in this century, it supplied water to steam locomotives that served nearby quarries. An iron trough near the base of the tufa apron has supplied water to an adjacent fish pond. Other small cave openings are visible in the bluff at approximately the same stratigraphic horizon. With the exception of the one immediately to the left (north) of the spring, most of these openings reportedly have little or no flow even after a heavy rainfall (Bowman and Reeds 1907). Beneath the dry cave opening immediately to the right (south) of the spring is a tufa deposit that is larger than that of the presently flowing Falling Spring.

Falling Spring represents a discharge point for the small groundwater basin on the plateau above (fig. 4). Because drainage of rainfall and snow melt is primarily through bedrock conduits, few streams are present in the western part of this upland area.

The chemical composition of water from the spring is controlled by the dissolution of limestone. This calcium-bicarbonate groundwater is saturated for most of the year with respect to calcite, aragonite, dolomite, and quartz (Panno and Weibel, unpublished manuscript). The aeration, agitation, and change in pressure (particularly from the spring to the base of the bluff) of the calcium-bicarbonate-saturated water as it cascades down the bluff promotes the release of carbon dioxide from the water and causes tufa to precipitate along the bluff (Herman and Lorah 1987). The aeration of the spring water along the bluff causes iron oxyhydroxide to precipitate (in a manner similar to the precipitation of scale in water-well plumbing), which darkens the apron of tufa along the bluff.

Davis et al. (1989) examined the tufa deposit and its biota in detail and described the deposit as occurring as a 1-meter-high, cone-shaped mound on a ledge above the base, and as a curtain between the ledge and the base, 5 m wide and 5 cm thick at the top, and 7 m wide and up to 55 cm thick at the bottom. They reported that the most dominant organism in the apron was blue-green algae, with the most abundant species being *Phormidium incrustatum*. Moss and a bacteria-laden mucilage were also observed on the tufa. The strands of algae and moss are apparently being encrusted by calcite and forming tangled clusters of parallel to subparallel, finger-like projections



Figure 3 Falling Spring, near Dupou, St. Clair County, Illinois, is a small cave spring that discharges from the St. Louis Limestone about midway up the high bluff. The spring is depositing tufa along the bluff face. (Stop 1)

that make up the apron. X-ray fluorescence analysis determined that Ca, Mg, SiO₂, and Fe were dominant at the surface of the tufa (Davis et al. 1989).

Discharge from the spring at base flow is clear and was measured by Panno and Weibel at approximately 38 L/sec. During and/or following heavy rains, discharge typically is laden with suspended solids, and the volume of discharge appears to be one or more orders of magnitude greater than that at base flow. As with most springs in Illinois' sinkhole plain, the water quality of Falling Spring is poor. The water is contaminated with a variety of coliform, fecal coliform (including *Escherichia coli*), and fecal streptococcus bacteria derived from natural and anthropogenic sources. Given the approximate recharge area for this spring (fig. 4), the likely sources of the fecal bacteria include livestock, pets, private septic systems, and natural sources. Bacterial concentrations of water samples from the spring (measured in colony-forming units per 100 mL of water) contained total aerobic bacteria counts of 300,000 cfu, total coliform counts of 4,000 cfu, and fecal coliform and streptococcus counts of 12 and 120 cfu, respectively (Panno et al., unpublished manuscript).

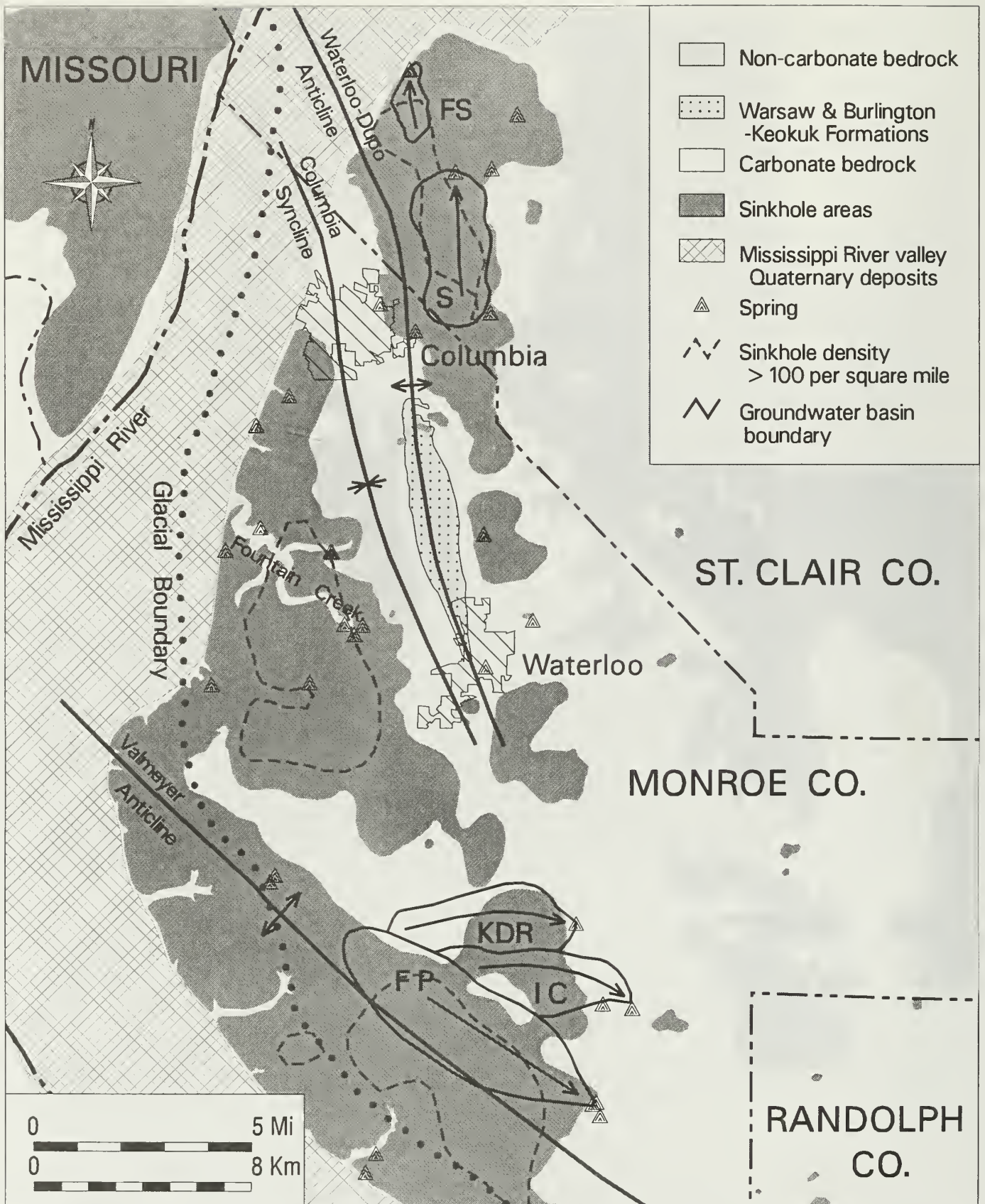


Figure 4 Map showing generalized pertinent geological and karst features of the sinkhole plain of Illinois. Elongate polygons indicate approximate groundwater basin boundaries (FS = Falling Spring basin, S = Stemler Cave basin, KDR = Kruger's Dry Run basin, IC = Illinois Caverns basin, FP = Fogelpole Cave basin). Arrows within basin boundaries indicate general flow directions of groundwater to discharge springs. Map modified after Mylius (1927), Weller and Weller (1939), and Weibel and Panno (1997).

3.9	0.0	Leave parking lot at Falling Spring Park.
4.0	0.1	Turn right onto LePere (turns into McBride Avenue).
5.2	1.2	Turn right onto Stolle Road and proceed east.
6.8	1.6	Proceed north onto Triple Lakes Road at fork. The road continues up onto the highlands and the sinkhole plain.
9.4	2.6	Stop sign at Zion Church. Continue south.
11.0	1.6	Park along road next to sinkhole pond and recently formed sinkhole.

Stop 2: Pond Collapse Sinkhole and Sparrow Creek Cave Spring

A. Pond Collapse Sinkhole (Section 35, T1N, R10W, St. Clair County) In the northern half of a larger, figure eight-shaped, 0.2-hectare sinkhole pond, a relatively new sinkhole drain formed during a storm that dropped 23 cm of rain over a two-day period in April 1996 (fig. 5). Hydrostatic pressure from the deepening pond initiated failure in the northern half of the pond, and water rapidly drained into a small cave at the bottom of the new collapse zone. Immediately after it formed, the cover-collapse sinkhole was characteristically cylindrical, 5.4 m in diameter, and 7.0 m deep. The snow-white, tooth-like projections of the epikarst have formed in the fossiliferous, oolitic Ste. Genevieve Limestone and are covered by reworked loess, mostly deposited as lacustrine sediments.

Attempts by the owner to seal and fill the sinkhole have failed because a concrete plug was installed after most of the hole was filled with soil and demolition debris. In spite of this effort, water continues to drain through pathways that formed around the concrete plug. Ideally, grouting of the bedrock conduit and the installation of a grouted-in-place, vertical drain pipe to the land surface should have been completed prior to backfilling the hole (Sowers 1984). Presently, the sinkhole is partially filled with demolition debris, and a pile of additional debris is adjacent to it awaiting final remediation.

Sinkholes similar to this one are characteristic of the sinkhole plain of southwestern Illinois (fig. 6). The largest sinkhole clusters by area and densest concentrations occur where the bedrock is the middle Mississippian limestone sequence composed of the Salem, St. Louis, and Ste. Genevieve limestones. The sinkhole plain is very large (fig. 4), and sinkhole densities are as great as 230 sinkholes per township section (approximately equal to 1 mi² or 2.6 km²) (Panno 1996).

In addition to the presence of soluble limestone bedrock, several other factors contribute to the occurrence of sinkholes. The elevated upland of the Mississippi River Valley provides the topographic relief for water to percolate downward to the level of the Mississippi River. Where the bluffs are steep, the area near the bluff edge commonly contains sinkholes and springs. To the south of the village of Columbia, a steep bluff is absent, and there is a gap between the sinkhole plains of St. Clair and Monroe Counties (fig. 4). This gap is underlain by the Columbia Syncline, which contains a Pennsylvanian outlier dominated by noncarbonate shale. Sinkholes are virtually absent within this area, except near the edge of the outlier, because the Pennsylvanian bedrock inhibits karst formation in the underlying Mississippian carbonate rocks. A parallel structure, the Waterloo-Dupo Anticline, occurs just east of the Columbia Syncline (fig. 4). Bedrock occurring along the crest of this structure consists of Warsaw Shale and the stratigraphically lower Burlington and Keokuk Limestones (Mylius 1921, Weller and Weller 1939). Sinkholes are absent where the Warsaw subcrops beneath the Quaternary mantle because the shale precludes karst formation. Karst features occur in the Burlington and Keokuk Limestones in other areas (Panno et al. 1997c,



Figure 5 A roughly 5-meter-diameter sinkhole that formed literally overnight during a particularly heavy rainfall. The white rock at the top of bedrock is the Ste. Genevieve Limestone and forms the epikarst. (Stop 2A)

Wicks 1997), but have not been seen in this area. These limestone formations are noted for the abundance of chert nodules and chert beds, which can have an arresting effect on epikarst formation. The area in which these units subcrop may be very small.

B. Sparrow Creek Cave Spring (Section 36, T1N, R10W, St. Clair County) Sparrow Creek Cave Spring is a partially submerged, 5-meter-wide, 2-meter-high opening at the base of a steep, loess-covered, blind stream valley (fig. 7). The stream issuing from the cave opening is the headwater of Sparrow Creek and is one of the largest springs (by discharge) in the state. Sparrow Creek Cave has a 245-meter-long, northward-trending main passage that leads to a sump, and a 300-meter-long side passage that becomes constricted at its distal end (Sherrill 1989).

On the basis of the chemical composition of water samples and maps of Stemler and Sparrow Creek Caves, this spring is believed to be the resurgence, or discharge point, of Stemler Cave (Panno and Weibel, unpublished manuscript). The entrance to Stemler Cave is at the bottom of a relatively large, 23-meter-deep sinkhole, located about 3.5 km to the south. To the south of the cave entrance, the passages are not accessible. Sherrill (1989) described the cave as having over 1.6 km of passages. The main passages in both Sparrow Creek and Stemler Caves are relatively large with flowing streams that are filled with pebbles, cobbles, and imbricated limestone slabs.

The Stemler Cave groundwater basin (fig. 4) is an elongate basin about 7 km long and 2 km wide with an area of approximately 18 km². Recent dye tracing indicates that its boundaries extend even farther south than shown on figure 6 (T. Aley, personal communication, 1998). The volume of groundwater flowing through Stemler Cave at the southern entrance was measured at about 150 L/sec at base flow. About three times that amount, approximately 470 L/sec, was measured discharging at Sparrow Creek Spring. Sherrill (1989) measured a discharge of 11,360 L/sec from the spring following a heavy rainfall. The cross-section morphology of the cave passages—for example,



Figure 6 An aerial view of Illinois' sinkhole plain looking west across the Mississippi River Valley toward Missouri.



Figure 7 Sparrow Creek Cave Spring is the distal end of Stemler Cave groundwater basin and is one of the largest springs in Illinois. (Stop 2B)

they are elliptical in the deeper parts of Stemler Cave—and descriptions by the cave owners suggest that during periods of high water, many parts of the cave system are completely flooded.

Illinois Caverns and Sparrow Creek, Stemler, Kruger’s Dry Run, and Fogelpole Caves are branchwork-type caves that occur primarily within the St. Louis Limestone. These caves initially formed along bedding plane partings. Attempts to define some of the groundwater basins of these caves have indicated that the local structural geology has a strong influence on the basin boundaries and groundwater flow direction. The long axis of the shape of both the Falling Spring and Stemler Cave groundwater basins parallels the axis of the Waterloo-Dupo Anticline (fig. 4). In addition, the general northward direction of groundwater flow in these basins parallels the northward plunge of this structure, whose crest is near Waterloo. In the southern part of Monroe County, the groundwater basins of Kruger’s Dry Run Cave, Illinois Caverns, and Fogelpole Cave are influenced by the Valmeyer Anticline, a southeast-plunging fold (fig. 4). The Fogelpole Cave groundwater basin parallels the anticlinal plunge to the southeast in both the long axis of its shape and its general groundwater flow direction. The long axes of the two other groundwater basins are oriented eastward and have groundwater flows in that direction, which suggests influences by both the axial plunge and the dip of the northeast limb of the structure.

11.0	0.0	Leave Stop 2 and continue south on Triple Lakes Road.
12.6	1.6	Turn right onto Columbia Road.
14.2	1.6	Turn right onto Stemler Road.
14.8	0.6	To the right is the sinkhole entrance to Stemler Cave (fig. 8).



Figure 8 View of the solution-enlarged fissure entrance of Stemler Cave. Water in the cave stream is just below geochemist Ivan Krapac.

- | | | |
|------|-----|--|
| 15.8 | 1.0 | Turn right onto Bluffside Road. |
| 17.8 | 2.0 | Turn right onto IL-158. |
| 20.4 | 2.6 | Stay to left to get to ramp for IL-3 south. |
| 20.5 | 0.1 | Cross over IL-3; entrance ramp curves sharply to the right. The exposures in the roadcut are limestones in the upper Warsaw Formation. |
| 21.1 | 0.6 | Roadcut reveals an exposure of Salem Limestone with soil-mantled epikarst features. |
| 26.3 | 5.2 | The highway becomes Business IL-3 entering Waterloo, IL. |
| 27.7 | 1.4 | Turn right onto IL-156 |
| 30.6 | 2.9 | Turn right onto Trout Camp Road |
| 31.2 | 0.6 | Turn right onto lane that is entrance to Camp Vandeventer |

32.0	0.8	Stop at Apache Campground
32.1	0.1	Continue on camp road through gates to parking area.

Stop 3: Camp Vandeventer Karst Area (Section 21, T2S, R10W, Monroe County)

Camp Vandeventer is owned by the Boy Scouts of America and provides camping, swimming, hiking, and other outdoor activities amidst an intensely karstified and picturesque landscape. The camp straddles Fountain Creek, a relatively large stream that has dissected the sinkhole plain. The Boy Scouts rented this site along the creek until 1928, when Judge Wilton M. Vandeventer, of East St. Louis, purchased about 27.5 hectares for a permanent camp (Voris 1998). The camp is in a truly unique geological setting, one that contains many sinkholes, a karst window, several caves and springs, and a seasonally sinking and resurgent stream.

The winding entrance road passes by numerous sinkholes that display a wide range of size, depth, and type (ponded and wetland). Across from the Apache Camp site is a karst window (fig. 9). A karst window is a special type of sinkhole that results from the total collapse of the cave roof up to the land surface. The water flowing through this “window to the underground” continues as an underground cave stream and discharges at the spring at the base of the bluff just below the Camp Vandeventer mess hall (Aley and Aley 1998). The beds of limestone that crop out at the bottom of the karst window are St. Louis Limestone. After heavy precipitation events, this sinkhole fills and overflows its rim at the north edge into a small channel that flows under the entrance road and cascades down a ravine to Fountain Creek. Recent slumping along the edges of this sinkhole indicates that during these periods of high water, significant erosion of the overlying Quaternary deposits occurs. During our visit to this site, a tracer test will demonstrate the connection between this karst window and the mess hall spring.

Fountain Creek is the largest stream in Monroe County and, as is typical for fluvial channels in karst terrains, has a reputation for being transformed into a raging torrent in a short period of time. At times of low flow, Fountain Creek is a sinking (losing) stream. Voris (1998) reported that during particularly dry periods, the stream may flow completely underground a few hundred meters downstream from the mess hall. The creek water returns to the surface channel about 0.4 km downstream and eventually flows into the Mississippi River, about 16 km west of the camp. This creek, which has dissected the limestone plateau, is the primary channel for small, unmapped groundwater basins that drain the surrounding limestone bedrock. Rainfall and snow melt on the plateau flows into nearby sinkholes and discharges into Fountain Creek at numerous springs at the base of the bluffs along the creek (fig. 4), including the springs at Camp Vandeventer.

The spring at the base of the 12- to 14-meter-high bluff below the mess hall is relatively large and discharges from a small cave in the St. Louis Limestone (fig. 10). The discharge of this spring, known as Camp Vandeventer Spring, was measured at about 35 L/sec at near base flow (Aley and Aley 1998). The spring flows directly into Fountain Creek through an entrenched channel that at one time was a water source for the camp. As with most springs in the sinkhole plain, the water from this spring is contaminated with fecal coliform bacteria; the spring is among the most severely contaminated ones in the sinkhole plain. The dominance of *Escherichia coli* in the spring water suggests that private septic systems are a primary source of the contaminants (Panno et al., unpublished manuscript). The presence of optical brighteners in the spring water supports these findings (Joan Bade, personal communication, 1997).

Another cave spring is located just to the west of this spring along the same bluff. Usually, the discharge from this spring is almost negligible. The spring, however, is an overflow for Camp



Figure 9 The karst window at Camp Vandeventer near the Apache Campground. This feature formed when the roof of the cave through which the water flows collapsed. The cave stream discharges in Fountain Creek below the camp mess hall at Camp Vandeventer Spring. (Stop 3)

Vandeventer Spring during flooding events (Panno et al. 1996), when the discharge is a characteristically high-energy, turbulent flow, and both the former and the latter springs discharge many hundreds to over a thousand liters per second (fig. 11).

Across Fountain Creek from both of the springs is a spectacular, natural exposure of St. Louis Limestone that displays numerous karst dissolution features (fig. 12). The upper portion of the bluff contains vertical joints that allow surface water to move downward into the bedrock. Small amounts of water move laterally along bedding planes and can be seen discharging from the bluff wall and flowing down the bluff face. A small, sediment-filled cave passage is visible at the base of the bluff.



Figure 10 Camp Vandeventer Spring is a typical large cave spring in southwestern Illinois. Groundwater discharges from a small cave at the base of a bluff composed of St. Louis Limestone. (Stop 3)

32.1	0.0	Leave Camp Vandeventer and return to Trout Camp Road.
32.9	0.8	Turn left on Trout Camp Road.
33.5	0.6	Turn left on IL-156.
36.4	2.9	Turn right onto IL-3.
39.6	3.2	Turn right onto Kaskaskia Road.
41.6	2.0	Turn left onto Co. Rt. KK.
42.8	1.2	Turn right onto Co. Rt. G.



Figure 11 A small cave spring adjacent to Camp Vandevanter Spring is hydraulically connected to the larger spring, but only during periods of high rainfall. At the time of this photograph, the water was at flood stage and both caves were completely filled with water. (Stop 3)



Figure 12 View of outcrop of St. Louis Limestone along Fountain Creek, opposite Camp Vandevanter Spring. Incipient vertical and horizontal conduits that have developed along joints and bedding planes in the bluff. (Stop 3)

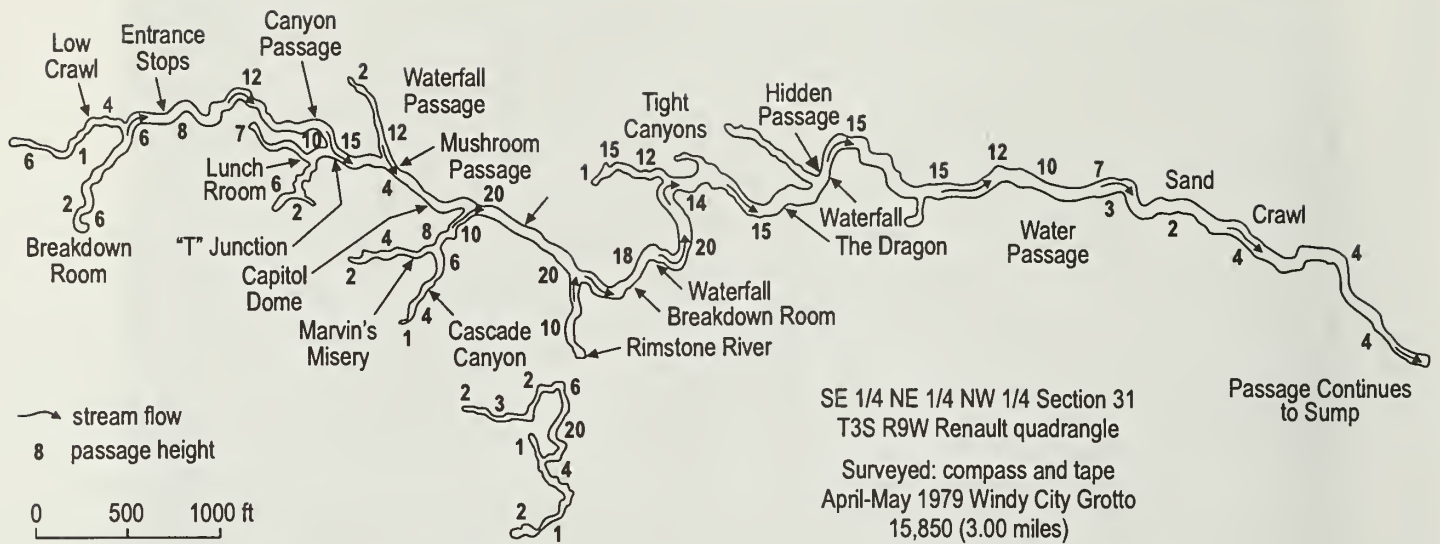


Figure 13 A map of Illinois Caverns, Monroe County, Illinois, showing features of interest within the cave (modified from Department of Natural Resources 1996). Numbers along passages indicate cave height in feet. (Stop 4)

44.7	1.9	Turn right at Illinois Caverns entrance lane.
45.1	0.4	Parking lot.

Stop 4: Illinois Caverns (Section 31, T3S, R9W, Monroe County)

Monroe County is the home of three of the largest caves in Illinois. Illinois Caverns is the second largest of the three and the only cave in the state ever to have been commercially developed. The cave is also known as Mammoth Cave of Illinois; the more famous Mammoth Cave in Kentucky occurs in lithologically and stratigraphically similar strata. Illinois Caverns was a tour stop of the 1904 St. Louis World's Fair and was reportedly visited by President Theodore Roosevelt. Attempts in 1901 and 1947 to make the cave into a commercial tourist attraction failed. The cave was sold to the State of Illinois in 1985 and is now a State Natural Area that is open to self-guided tours throughout the year. The cave has approximately 9.6 km of mapped passages (fig. 13); most contain streams that are actively enlarging passages. The cave contains various types of speleothems, dissolution features, and numerous cave-adapted biota that crawl, fly, and swim within the passages. Approximately 6,000 people visited the cave in 1997, and the number of visitors, which include student groups from Illinois and Missouri, has been increasing annually.

Illinois Caverns was initially mapped by Bretz and Harris (1961). It is a branchwork-type cave that formed along bedding planes within the St. Louis Limestone. It has a large trunk cave passage and numerous tributary channels, some of which are locally controlled by joint orientations. The cave entrance is at the bottom of an elliptical sinkhole that measures about 35 by 45 m; the floor of the cave is about 33 m below the rim of the sinkhole. A stream flows down the center trunk of the cave and discharges from Dye Spring, 5 km to the southeast (Wightman 1967), before flowing into Horse Creek and eastward into the Kaskaskia River. The land surface above Illinois Caverns contains many sinkholes. Land use is dominantly agricultural (primarily row crops and, to a lesser extent, livestock).

Water enters Illinois Caverns from three sources: surface runoff through sinkholes, soil water or groundwater temporarily perched on top of bedrock (the epikarst), and the shallow karst aquifer. Runoff into sinkholes is episodic and occurs during and after significant rainfall events. Water

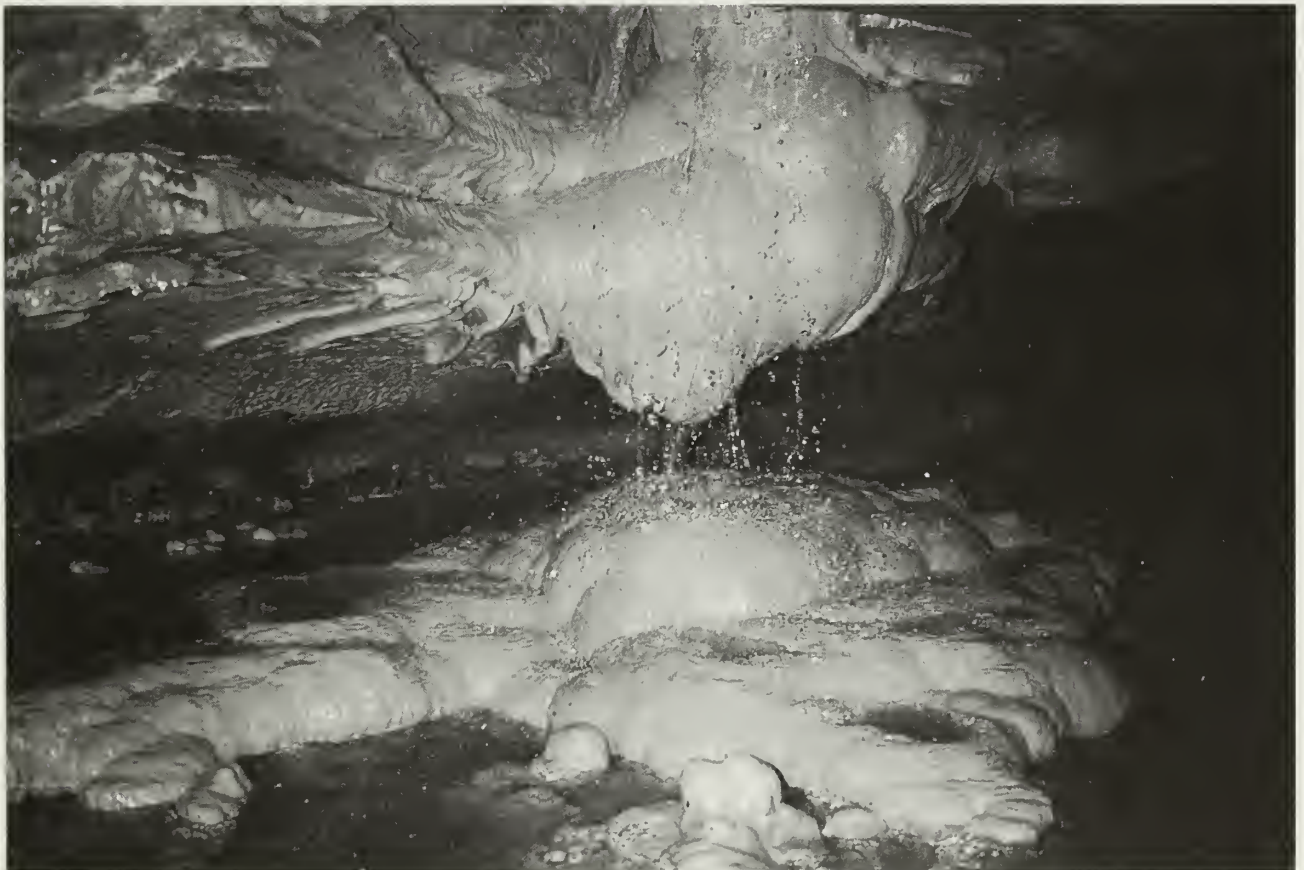


Figure 14 Stalagmites, stalagmites, and flowstone are abundant in the passages of Illinois Caverns. Speleothems of this size may take thousands to tens of thousands of years to form and are evidence of the infiltration of groundwater saturated by calcium carbonate. Top photo taken at the Lunch Room, bottom photo taken just east of the Mushroom passage.

entering the cave system in this manner typically is laden with suspended solids and floods the cave passages. Soil water or groundwater perched on top of limestone bedrock (within the epikarst) in some areas of the sinkhole plain may extend into the soil zone up to about 1 m or more above the soil–bedrock interface. The perched groundwater is channeled to areas of lower elevation where it may find a crevice or fracture through which it will seep (Panno et al. 1998). Where water seeps into Illinois Caverns, it either dissolves the cave ceiling to form chimneys or forms flowstone within the passages (fig. 14). Groundwater seeping into the cave from the shallow karst aquifer provides base flow for the cave stream and Dye Spring and is an approximation of the overall water quality for the shallow karst aquifer within the Illinois Caverns groundwater basin (Quinlan 1988).

The temperature of the stream and air in the cave is about 11° to 12°C and lacks significant seasonal variation. Stream water is clear most of the time, but turns to a cloudy or coffee-brown color during or immediately following a large rainfall. All water entering the cave may be contaminated with relatively high counts of fecal coliform and other types of bacteria from natural sources, livestock, and private septic systems and is not fit to drink. Nitrate concentrations (as N) in cave stream water rarely exceed 6.5 mg/L and average 5.4 mg/L. Although these concentrations exceed the natural background of approximately 1.4 mg/L (Panno et al. 1996), they do not exceed the 10 mg/L regulatory limit for drinking water set by the U.S. Environmental Protection Agency (U.S. EPA 1991).

The entrance to Illinois Caverns is a good example of a joint-controlled, solution-enlarged fracture (fig. 15). It originally was a narrow joint in the limestone bedrock through which soil water and rain water flowed down the approximately 26 m to reach the conduit system that is now Illinois Caverns. Initially, the fracture probably was paper-thin in width. Over thousands to tens of thousands of years, the limestone walls of the fracture dissolved as the slightly acidic water from the land surface flowed past them. As the fracture widened, the volume of infiltrating water and the dissolution rate of the fracture walls increased. When the fracture enlarged enough to allow soil to fall into it, sinkhole formation was initiated. The fracture eventually widened to more than 1 to 1.5 m, and as it did so, the sinkhole grew to its present depth of approximately 26 m.

The original conduit, or protocave, that formed when slightly acidic, surface-derived water slowly enlarged a channel between bedding planes is preserved in the ceiling in some parts of the cave (fig. 16). One of the best examples in this cave is in Canyon Passage, where the original conduit is visible in the ceiling. This protocave is about 10 to 15 cm wide and is the upper half of a tubular conduit that follows the general trend of the cave. Over tens to hundreds of thousands of years, as water migrated through the conduit, it enlarged downward and laterally to form the much larger passage that is present today.

Rectangular, elliptical, and canyon-shaped passages are present in Illinois Caverns. The cross-sectional shapes of cave passages tell much about the origin and history of a cave. The shape of a conduit or cave passage depends on hydrodynamic forces of groundwater flowing through the cave (White 1988). Circular or elliptical passages form when conduits are completely filled with groundwater during formation. Water then dissolves wall rock equally in all directions to form “phreatic” cave passages. The downcutting of a free-surface cave stream forms sinuous canyon passages with near-vertical walls (fig. 17). All other passage geometries are modifications or combinations of elliptical and canyon-shaped passages (White 1988), although abundant stalactites, stalagmites, flowstone, and breakdown tend to obscure these geometries.

Cave passages above the present stream passage can be seen in several places in the cave (fig. 18). Excellent examples are located just above the first waterfall and where the path follows a ladder to the dry upper passage and avoids the lower, wetter stream passage. The ceiling of the upper passage also contains a remnant of the original bedding plane conduit.

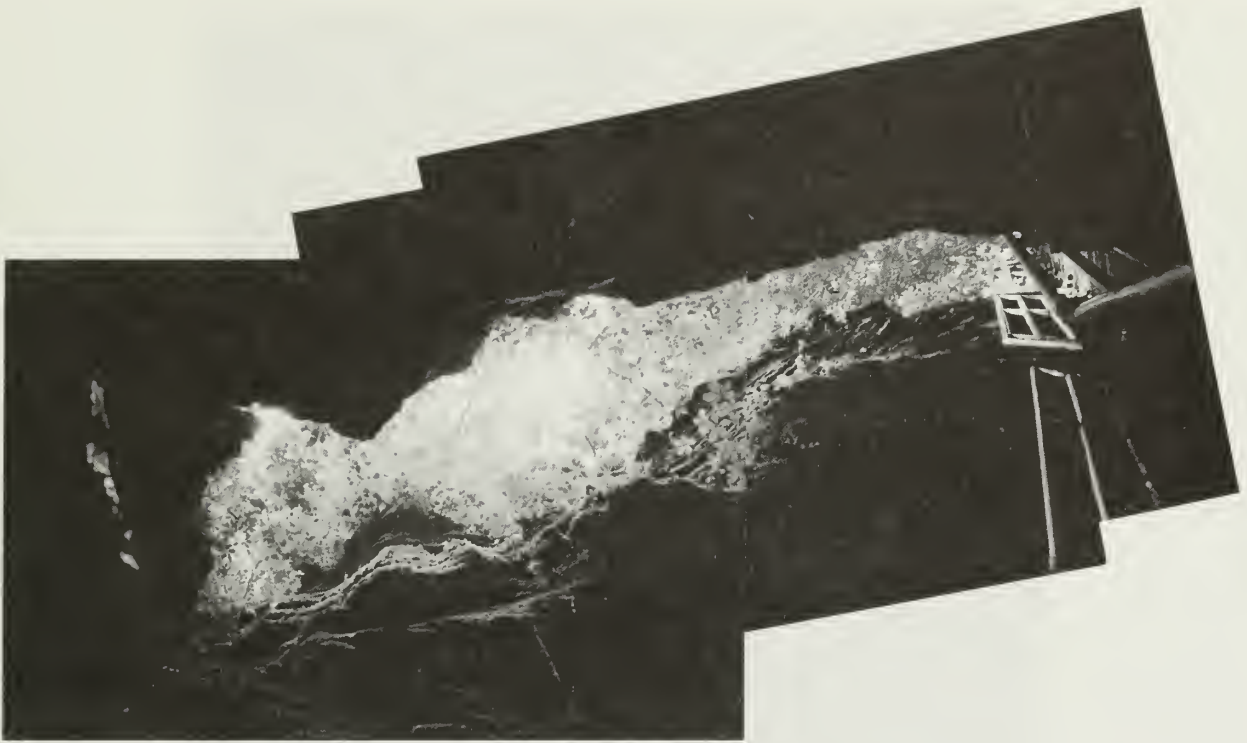


Figure 15 The entrance to Illinois Caverns (looking up from the cave) is a solution-enlarged fracture at the bottom of a sinkhole at Illinois Caverns State Natural Area. (Stop 4)

Scallops are smooth, shallow, concave indentations that are common along the walls of cave stream passages (fig. 19). Scallops look as though an ice cream scoop was used to remove portions of the rock. They are common where the stream flows across rock faces and are best observed during periods of low water. Because they are dissolved out of the limestone by flowing, turbulent water, the geometry and size of the scallops can be used to determine the direction of water flow and its velocity. A steeper face occurs on the upstream side. The larger the size of the scallops (some exceed 30 cm in diameter), the slower the velocity of the water flow that formed them, and vice versa (White 1988). The scallops in Illinois Caverns average about 6 cm in diameter.

Throughout the cave are numerous bowl-shaped depressions that formed in the bedrock just above and adjacent to the stream (fig. 20). Several are adjacent to the first downstream waterfall. These “potholes” are the result of cobbles and pebbles being trapped within small depressions in the stream bed. Eddy currents from flowing water during high-flow events cause the limestone or chert cobbles and pebbles to swirl in a circular motion. This swirling, over time, creates hemi-ellipsoid or bowl-shaped depressions that may range from 10 to 30 cm in diameter and 10 to 15 cm deep. Many of the rocks that created these features have either been pulverized or removed from the bottom of the potholes along the path by visitors.

Rimstone pools are among the most picturesque features in Illinois Caverns (fig. 21). Examples include Cascade Canyon and Rimstone River, which are side passages made up of a series of pools. Rimstone pools are small pools of water surrounded by dams of precipitated calcite. The pools typically form within and near the point where side passages enter the main cave passage. Groundwater that is saturated to supersaturated with calcite flows through small pools within natural depressions and across relatively rough surfaces at the margins. The agitation at the margins accelerates loss of carbon dioxide from the water and initiates precipitation of calcite (Herman and Lorah 1987, White 1988). The calcite deposits form smooth, flowstone dams at the edges of the pools. Rimstone pools are usually found in series, with one pool spilling into adjacent pools.



Figure 16 The upper half of the original conduit (protocave) that became Illinois Caverns is preserved in the ceiling of Canyon Passage. (Stop 4)

Rubble zones, also referred to as breakdown, are piles of slab-shaped rocks that, prior to collapsing, formed part of the ceiling of the cave. In Illinois Caverns, the best examples can be examined in Breakdown Room. White (1988) stated that “the weight of rock above a solution cavity causes the beds to sag slightly into the opening. If the beds are flat-lying, there is a concentration of shear stress at the passage walls. . . . If the beds do not have sufficient strength, they shear and collapse into the cavity.” Given enough time, groundwater flowing through and over the jumbled slabs of limestone will eventually dissolve them. Collapse of rock slabs from the roof can reduce the spans of individual beds and create a more arch-shaped roof that is structurally more stable than a wide expanse of a single bed.

Twelve species of bats are found in caves and abandoned mines in Illinois. These subterranean habitats are used for daytime roosts during the summer and serve as hibernacula in the winter. Four state-listed and two federally-listed endangered species of bats occur in the state; the federally-listed species are the Indiana bat (*Myotis sodalis*) and the gray bat (*M. grisescens*) (Hofmann and Gardner 1990). The bats typically found in Illinois Caverns include the little brown



Figure 17 Sinuous cave passages, lined with flowstone, are typical of the canyon passages of Illinois Caverns. This particular area contains large stalactities. (Stop 4)

bat (*M. lucifigus*) and the eastern pipistrelle (*Pipistrellus subflavus*) (J. E. Gardner, personal communication, 1993). Cave salamanders are also plentiful in pools and on the walls of Illinois Caverns. The cave salamander (*Eurycea lucifiga*), which is relatively small and orange with black spots, is a true troglophile—its entire life cycle takes place in caves (Taylor and Webb 1998).

45.1	0.0	Leave Stop 4, turn left onto Co. Rt. G.
47.0	1.9	Turn right onto Co. Rt. KK.
47.8	0.8	Turn left onto Sportsman Road.
48.7	0.9	Turn right onto IL-3.
57.8	9.1	Enter Redbud; turn right and continue on IL-3.



Figure 18 An abandoned upper passage in Illinois Caverns, about 1 m square and 8 m long, occurs just above the first small waterfall downstream of the cave entrance. (Stop 4)

63.1	5.3	Enter Ruma.
67.6	4.5	Cross Kaskaskia River. Evansville is to the left.
73.5	5.9	Enter Ellis Grove.
82.2	8.7	Enter Chester. Turn right on by-pass road to bridge.
83.4	1.2	Mississippi River bridge (MO-51).
89.7	6.3	Cross Ste. Genevieve Fault Zone.
95.0	5.3	Intersection of Business MO-51 and By-Pass MO-51. Proceed straight on By-Pass MO-51.
98.5	3.5	I-55 overpass.



Figure 19 Scallops are common features through the cave; their size is an indicator of relative stream velocity (Stop 4).

HYDROGEOLOGY OF SHALLOW KARST GROUNDWATER SYSTEMS IN SOUTHEASTERN MISSOURI

0.0	0.0	Road log resumes at Exit 129, I-55 and MO-51 at Perryville, Missouri. Turn left (north) onto MO-51.
1.0	1.0	Turn right (east) onto Edgemont Boulevard.
1.4	0.4	Turn right (south) onto Big Spring Boulevard.
2.2	0.8	Turn left (east) onto Veterans Drive.
2.3	0.1	Enter Perryville Country Club parking lot.

Stop 5: St. Peter Sandstone Outcrop (Perryville Country Club, T35N, R10E, Perry County)

Stops in the Perryville karst area will explain the complex nature of its subsurface drainage, the interrelationships between many of the area karst features, and the problems of urbanization in this unique karst area (fig. 22).

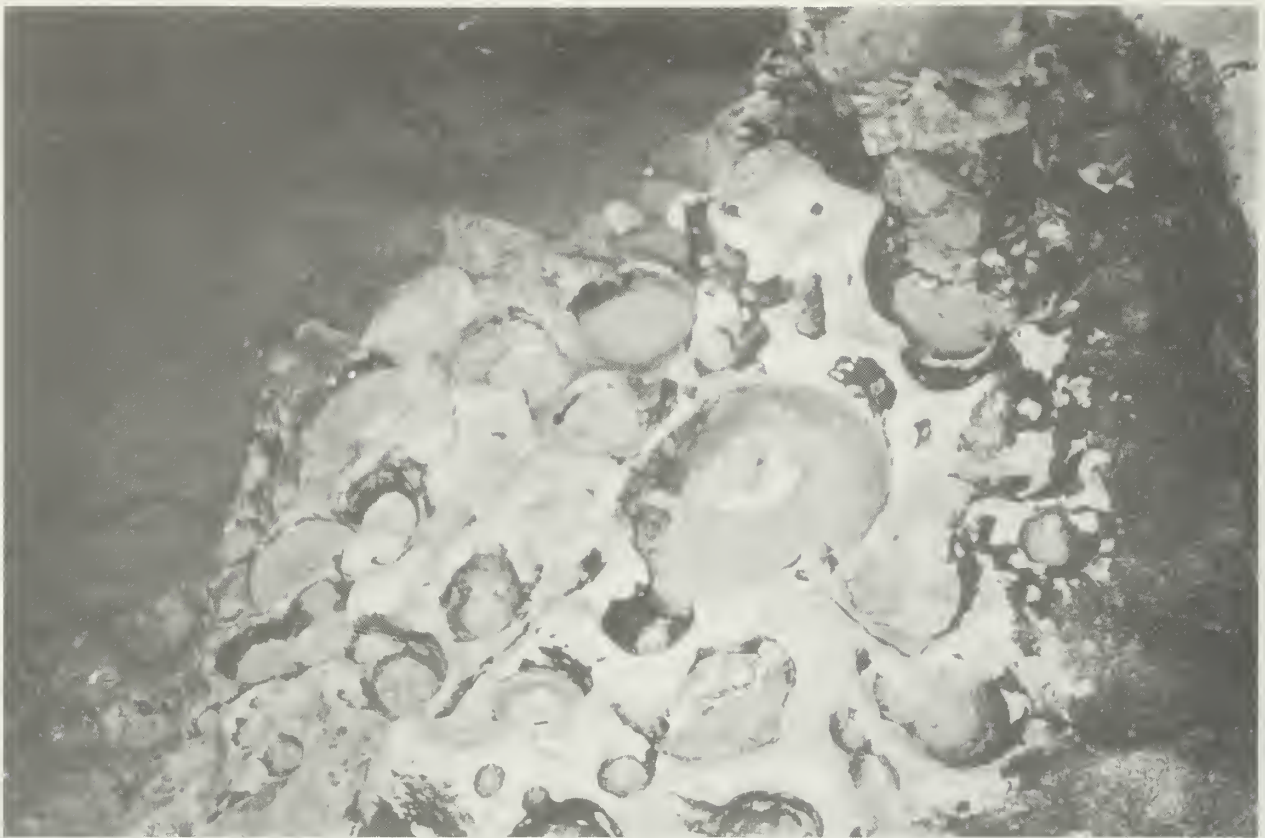


Figure 20 Potholes in the top of limestone beds just above the stream channel formed when the stream channel was not so deeply entrenched or at times of high water. Natural depressions in the rock trapped cobbles and pebbles that spun and scoured the bowl-shaped features. (Stop 4)

Perryville is in the western part of Perry County where lower Ordovician (Canadian) dolomites and sandstones are well below land surface, and younger Ordovician (Champlanian) strata crop out. The St. Peter Sandstone generally forms the base for karst development in the Perryville karst area. The St. Peter is a fine- to medium-grained quartzose sandstone that ranges from 20 to 60 m thick, and averages about 23 m at Perryville.

The St. Peter is unconformably overlain by the Joachim Dolomite, which forms the bedrock surface throughout the central part of the Perryville karst area. The Joachim is about 76 m thick in the area, and is yellow brown, silty dolomite containing limestone interbeds and minor shale. The Plattin Formation, which overlies the Joachim, is about 106 m thick and forms the bedrock surface throughout most of the eastern part of the Perryville karst area. It is a gray, finely crystalline to sublithographic limestone with minor shale. The Joachim and Plattin both thicken to the east.

Although the Plattin is the youngest bedrock unit exposed in the Perryville karst area, a short distance northeast of Perryville, extensive faulting along the Ste. Genevieve Fault system has moved Mississippian rocks down enough to abut Ordovician Champlanian strata.

Both the Joachim and Plattin contain numerous karst features. Many sinkholes are found in the Plattin, but the Joachim is host to the major caves and springs of the area. Perry County currently has 622 known caves; most are in the Joachim Dolomite. Four major caves in eastern Perry County, all within 8 km of Perryville, contain more than 112 km of mapped passages.

At this stop, the St. Peter Sandstone exhibits sinkhole development, which is unusual for the formation (fig. 23). The sinkholes in the St. Peter are due more likely to solution activity and collapse in the underlying Everton Formation than to dissolution of the St. Peter itself. About 10 hectares on the west side of Big Spring Boulevard drain into the ephemeral stream that flows into a conduit developed in the St. Peter Sandstone. The water is channeled underground a short distance to Big



Figure 21 A series of rimstone pools occurs in Cascade Canyon. (Stop 4)

Spring, which is one of the smaller springs in the Perryville karst area. Drainage through the conduit is somewhat sluggish, though, and water floods over Big Spring Boulevard after heavy rainfall. (Note to geologists who also golf: The sinkhole is played as a hazard and is filled with golf balls.)

2.3	0.0	Leave Stop 5; backtrack to Edgemont Boulevard by way of Big Spring Boulevard.
3.6	1.3	Turn right (east) onto Edgemont Boulevard.
4.9	1.3	Turn left (north) onto Waters Street.
5.3	0.4	Turn left (west) onto Grand Street.
5.6	0.3	Turn right (north) onto Bruce Street.

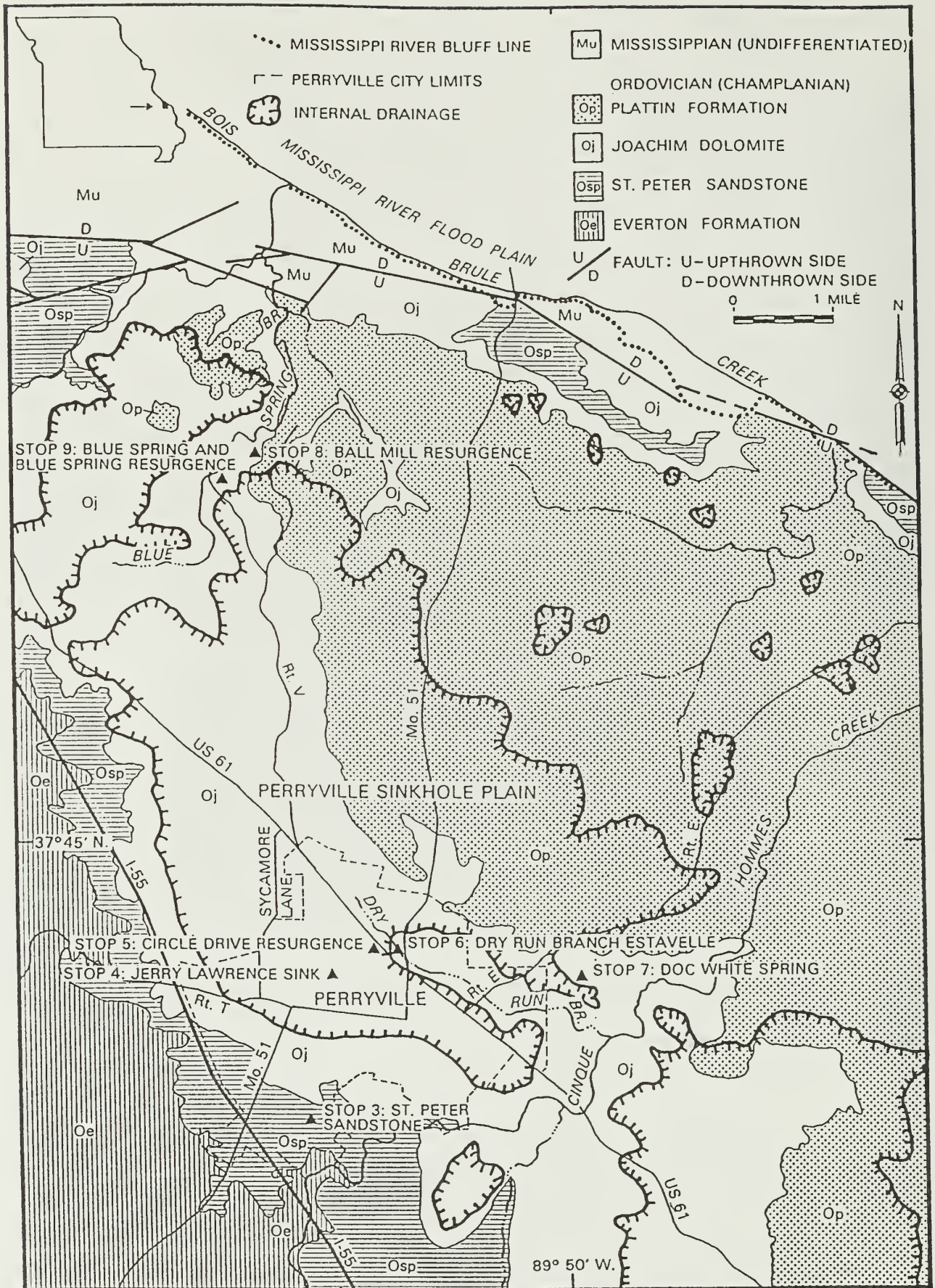


Figure 22 Geologic map and field trip stops for the Perryville sinkhole plain portion of the field trip (modified from Vandike et al. 1989).



Figure 23 An exposure of Ordovician St. Peter Sandstone in a large sinkhole at the Perryville Country Club shows dissolution features. (Stop 5)

- | | | |
|-----|-----|-------------------------------------|
| 5.7 | 0.1 | Turn right (east) onto Star Street. |
| 5.8 | 0.1 | Park at end of Star Street. |
-

Stop 6: Jerry Lawrence Sink (Perryville, T35N, R10E, Perry County)

Jerry Lawrence Sink is an eastward extension of a large shallow uvala in the Joachim Dolomite in the western part of Perryville. Before extensive modification and drainage improvement, the sinkhole flooded after heavy rainfall. During construction activity in the sinkhole, Streiler City Cave was rediscovered. The entrance of the cave, which was choked with accumulated debris and brush, was excavated. A 1-meter-diameter concrete pipe was laid from the entrance to about 60 m southwest. Two storm-water drainage wells were constructed to channel water from the sinkhole into the upstream reaches of the cave (fig. 24A). The pipe leading into the mouth of the cave is now an overflow inlet and only functions when storm-water drainage wells are overwhelmed by heavy runoff (fig. 24B). A once-planned subdivision that would have been subject to flooding during heavy rainfall is now a storm-water retention and disposal basin. In addition, Perryville has recreational facilities in the sinkhole.

Jerry Lawrence Sink continues to the west on the other side of Bruce Street. This westward extension drains nearly 1.2 km². The water is channeled into the subsurface through a throat just west of Bruce Street. Water enters a conduit related to the Streiler City Cave and eventually emerges at several karst resurgences to the east. The hydrogeology of the Perryville karst area is complex. Vandike (1985b) used extensive dye tracing to determine the outflow points of runoff in the karst area (fig. 25). The Perryville sinkhole plain covers about 41 km² and has continuous internal



Figure 24 Jerry Lawrence Sink is a large sinkhole that is used to dispose of surface runoff via Streiler City Cave. Water is channeled through exposed segments of the cave (*top photo*) and cascaded down caged entrances (*bottom photo*) to the main part of the cave system. (Stop 6)

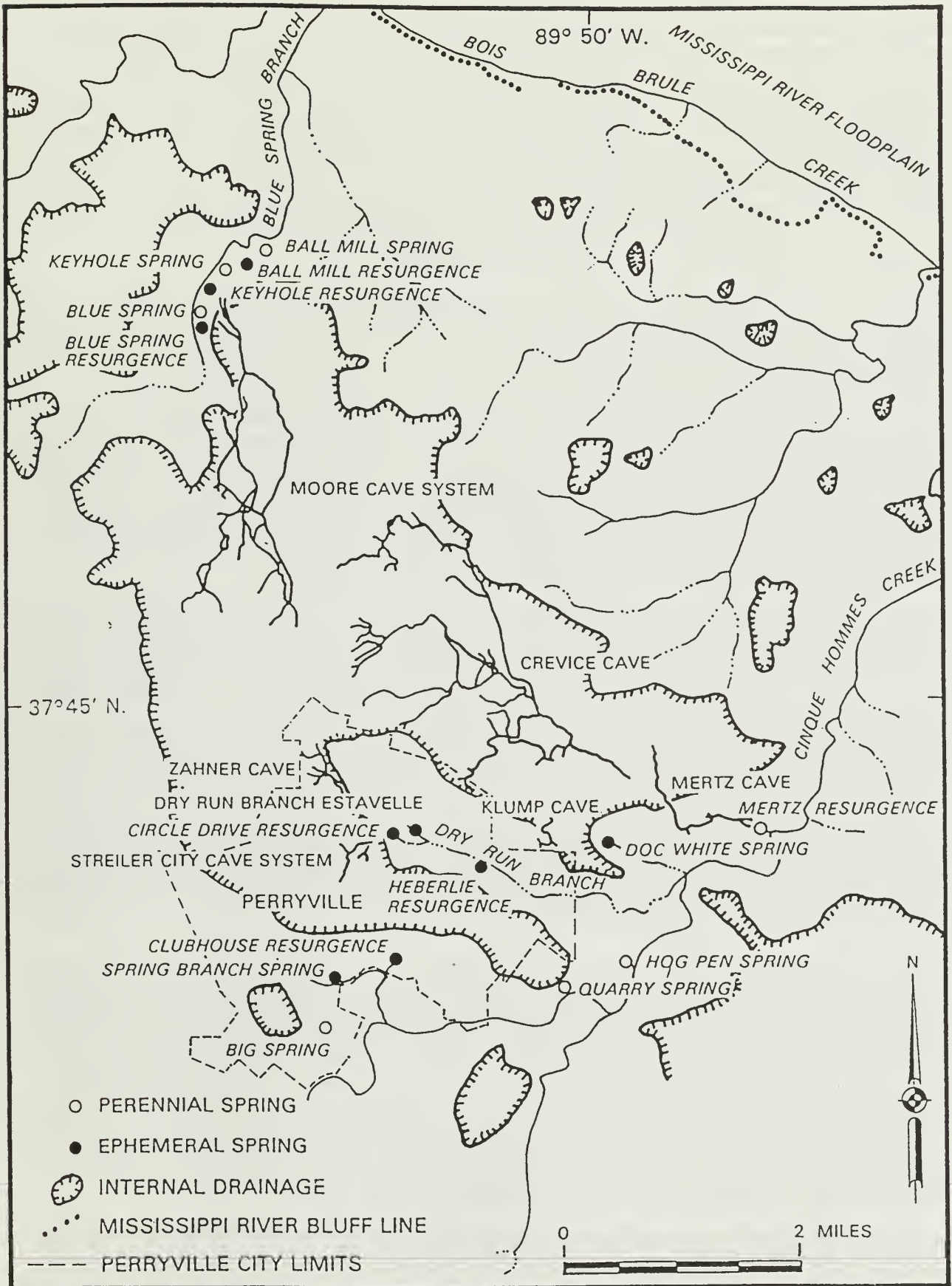


Figure 25 Major springs, resurgences, and caves in the Perryville karst area (modified from Vandike 1985b).

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drainage. Springs and karst resurgences along the land surface drain to the northwest and southeast. Discharge water that had entered the subsurface through sinkholes in the sinkhole plain is drained to the northwest (Blue Spring Branch) and southeast (Cinque Hommes Creek). Two major cave systems transport the water. The Crevice Cave system, which consists of several hydrologically connected caves (including Crevice, Mertz, Klump, Streiler City, and Zahner Caves), drains approximately the eastern two-thirds of the Perryville sinkhole plain. The Moore Cave System, which includes Berome Moore Cave, Tom Moore Cave, and other smaller caves, drains approximately the western third. These cave systems are among the largest in Missouri. Crevice Cave alone has more than 43 km of mapped passages and is strongly joint controlled. The Moore Cave system has more than 27 km of mapped passages.

Dye tracing has shown that water entering sinkholes in Perryville primarily drains through a southern branch of the Crevice Cave system and emerges at several hydrologically connected springs and karst resurgences. The base-flow outlet of the system is the Mertz Resurgence, about 5 km east of Perryville on the north side of Cinque Hommes Creek. Mertz Resurgence discharges much of the runoff entering the karst groundwater system in Perryville; but upstream from the resurgence are at least four other groundwater outlets that can, depending on hydraulic head in the cave system, discharge a portion of the water. Mertz Resurgence drainage in Perryville is divided into three subbasins: Circle Drive Resurgence, Heberlie Resurgence, and Dry Run Branch Estavelle. Circle Drive Resurgence and Heberlie Resurgence are essentially overflow outlets for the subsurface drainage network and discharge water only after heavy rainfall. Depending on runoff levels, Dry Run Branch Estavelle can function as a spring or sinkhole.

Only a portion of the karst recharge discharges from Circle Drive and Heberlie Resurgences and Dry Branch Estavelle. The remainder continues downstream in the conduit system toward the Mertz Resurgence. Doc White Spring, an intermittent spring between Perryville and Mertz Resurgence, is another overflow outlet for this karst groundwater system. It is dry much of the time, but begins discharging water after moderate runoff occurs and before the other overflow outlets in Perryville begin discharging. Like other upstream resurgences, it discharges only a portion of the water entering the conduit system. The remainder is transported on to Mertz Resurgence.

Jerry Lawrence Sink and Streiler City Cave are near the upstream end of this karst drainage system. Dye introduced into Jerry Lawrence Sink is recovered only at the Mertz Resurgence during relatively dry weather. If there is ample runoff to cause discharge at Doc White Spring, dye will also emerge there. After very heavy rainfall, dye will also be recovered from Circle Drive Resurgence.

Problems with sinkhole drainage date back to the early days of the city. For years, private individuals installed drainage wells in the bottoms of sinks. Storm-water drainage wells placed in Jerry Lawrence Sink are a common sight in Perryville. Today, the city has easements on many of the drainage wells and installs most of the new ones. Sinkhole modification is controlled by city ordinance, which requires a permit before modifications can take place. Most of the drainage wells are less than 6 m deep and consist of large-diameter concrete pipe. The sinkholes are excavated until bedrock openings are encountered. Precast concrete pipe is set over the bedrock openings, a gravel pack is placed around the lower part of the concrete pipe, and the hole is backfilled to original grade. A trash rack completes the installation (Vandike 1987).

Further development in sinkholes will soon be limited. In a study funded by the city of Perryville, Vandike (1988) calculated expected water levels in 58 sinkholes in the city under various rainfall, runoff, and outflow conditions. This information will be used by the city to establish minimum construction elevations for sinkholes in Perryville.

5.8	0.0	Leave Stop 6.
5.9	0.1	Turn left (south) onto Bruce Street.
6.2	0.3	Turn left (east) onto MO-51. Stay on MO-51.
7.5	1.3	Turn right (south) onto MO-61.
8.1	0.6	Turn left (north) onto St. Rt. E.
9.2	1.1	Turn right (east) onto unnamed lane.
9.3	0.1	Park at end of lane near barn.

Stop 7: Doc White Spring (Section 16, T35N, R11E, Perry County)

Doc White Spring (fig. 26) is about 1.6 km east of Perryville, in the upper watershed of an unnamed tributary of Cinque Hommes Creek. Like many karst groundwater outlets, it is intermittent. The water rises at the base of a low bluff of Joachim Dolomite from a subvertical cave opening. Water originally flowed through breakdown and debris. In 1984, a backhoe was used to remove debris blocking the spring opening in hopes of finding an entrance for exploring and mapping this portion of the Crevice Cave conduit system. The spring was found to rise from a submerged opening at the side of an oblong room about 6 m long and 2 m wide. Even during dry weather, there is insufficient air space for exploration in the conduit. Discharge from the spring is highly variable. The spring ceases to flow during dry summer weather, but after heavy rainfall will discharge an estimated 1,100 L/sec.

Perhaps more fascinating than the spring itself is the geomorphology of the immediate setting. The area near the spring and part of the spring branch are collapsed cave passages. A bedrock pillar, some tens of meters in diameter, 3 m high, and less than 1 m from the spring, appears to be a remnant of cave wall between intersecting cave passages. At the base of the pillar, on the spring side, is a small, vertical-sided sinkhole about 1.2 m in diameter and depth. Even after the spring stops flowing in dry weather, water continues to flow through the bedding-plane opening at the base of the sink. Dye introduced into this small sinkhole was recovered in the cave stream of Mertz Cave, 1.4 km to the northeast, and Mertz Resurgence, 1.9 km northeast of Doc White Spring.

Doc White Spring is a middle-level overflow outlet for the conduit system that channels water from the western part of the Perryville sinkhole plain to Mertz Resurgence. Like Circle Drive Resurgence and Dry Run Branch Estavelle, it discharges only a portion of the water flowing through the conduit system. Mertz Resurgence is the outflow point for the water remaining in the system downstream from Doc White Spring.

Mertz Resurgence is the downstream entrance of Mertz Cave. A completely water-filled passage in lower Mertz Cave prevents entry from the resurgence. The only usable entrance to Mertz Cave is through a deep sinkhole 1.3 km northeast of Doc White Spring. Mertz Cave contains about 3.6 km of mapped passages. It is actually a downstream continuation of Crevice Cave. Dye tracing has proved the hydraulic connection, but a flooded passage prevents cavers from making a physical connection. Water from the Circle Drive Resurgence, Dry Run Branch Estavelle, Heberlie Resurgence, and the Doc White Spring recharge area is thought to enter Mertz Cave about 0.7 km upstream from the sinkhole entrance.

At Mertz Resurgence, water flows from a horizontal cave passage in the Joachim Dolomite. Plattin Formation caps the hill at the top of the 30-meter-high bluff above the spring outlet. The cave can

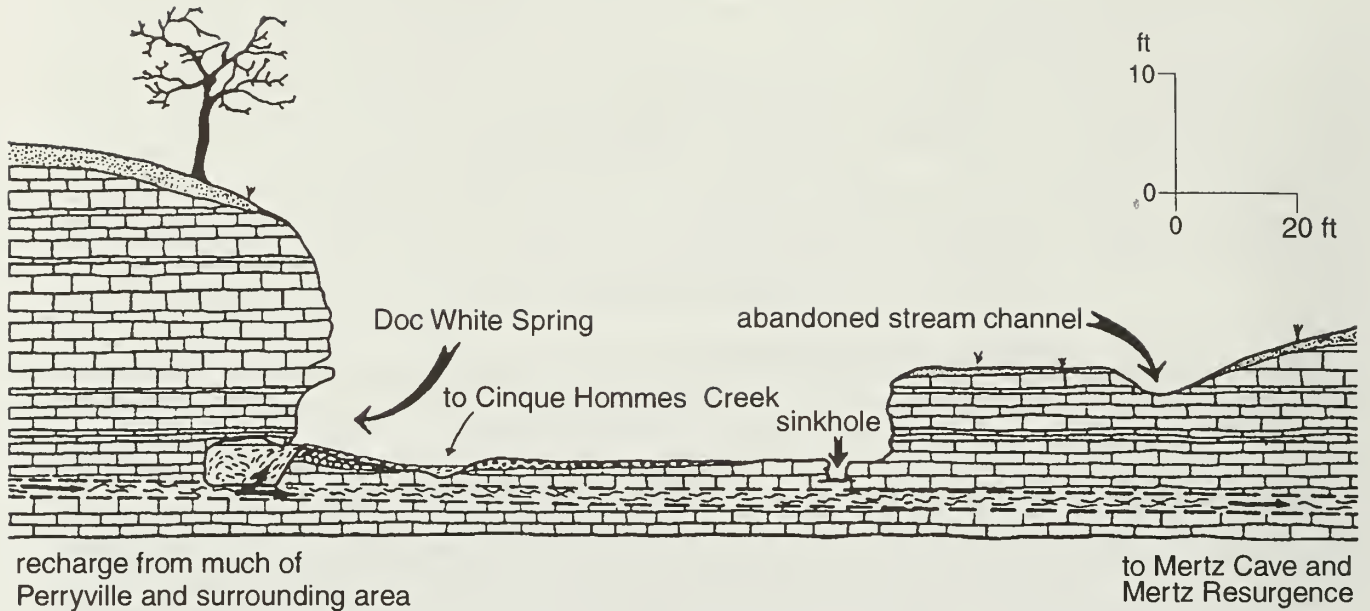


Figure 26 Diagrammatic cross section of Doc White Spring, looking north-northeast (from Vandike et al. 1989). Groundwater discharges from the spring, flows on the land surface for a short distance, and disappears into a sinkhole. (Stop 7)

be followed upstream only a short distance until the passage siphons. This resurgence is the only perennial spring of the Crevice Cave system. It is about 24 m lower than Doc White Spring and 46 m lower than Circle Drive Resurgence. Flow from Mertz Resurgence during very dry weather may decline to less than 6.3 L/sec, but after very heavy rainfall flow has been visually estimated at more than 180 L/sec.

9.3	0.0	Leave Stop 7; backtrack to MO-61 along St. Rt. E.
10.5	1.2	Turn right (west) onto MO-61.
12.9	2.4	Turn right (north) onto St. Rt. V.
13.5	0.6	Bear right.
15.7	2.2	Bear right at fork in road.
16.3	0.6	Bear left at fork in road.
17.1	0.8	Park at Ball Mill Resurgence parking area.

Stop 8: Ball Mill Resurgence (Section 24, T36N, R10E, Perry County)

The previously discussed Perryville karst area groundwater outlets drain into Cinque Hommes Creek, which bounds the area to the southeast. Blue Spring Branch forms the northwest boundary of the karst area, and along its reach are several important and interesting springs and karst resurgences.

The most unusual karst resurgence draining the Perryville sinkhole plain is Ball Mill Resurgence (fig. 27), located at the base of a 12-meter-high bluff of Joachim Dolomite, a short distance south of Blue Spring Branch. The feature is a very large pothole and topographically looks more like a



Figure 27 C.P. Weibel and S.V. Panno stand at the bottom of hemispherically-shaped Ball Mill Resurgence. The cobbles that line the resurgence scoured the feature in a manner similar to that of the bowl-shaped features of Illinois Caverns. (Stop 8)

sinkhole than a spring. The rise basin, about 6 m in diameter and 2.4 m deep, is completely dry most of the time. After light rainfalls, it probably channels a minor amount of runoff into the groundwater system. After a very heavy rainfall, its function, although brief, cannot be mistaken. Water surges through the well-rounded cobbles at the bottom of the basin and flows down to Blue Spring Branch. The natural milling of rocks striking each other when flood water rushes upward through the cobbles creates the rock “balls” covering the floor of the resurgence. Fresh rock spalling from the bluff above keeps the mill supplied with abrasives and raw materials to replace the dolomite cobbles as they are ground away.

The very brief functioning of the resurgence after heavy precipitation indicates that its recharge area is fairly small but very open and interconnected. Vineyard (personal communication, 1984) visited it after a heavy rainfall and estimated the observed resurgence discharge at 0.5 L/sec. Vandike (1985b), using high-water marks and channel characteristics, estimated peak flow at over 1.5 L/sec. Ball Mill Spring, another groundwater outlet between Ball Mill Resurgence and Blue Spring Branch, has a well-sustained base flow and may be a lower level outlet for the conduit system that channels water to Ball Mill Resurgence.

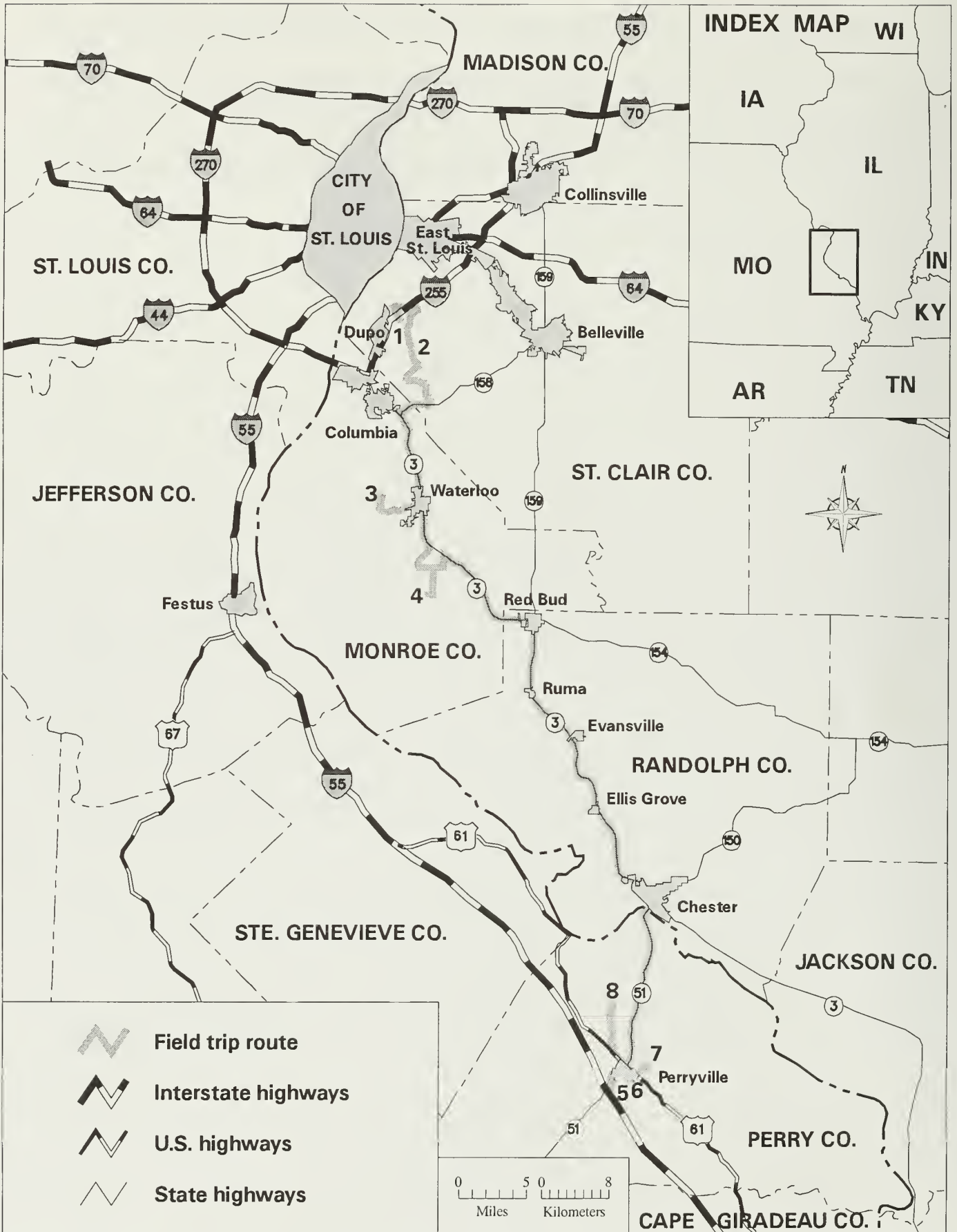
17.1	0.0	Leave Stop 8, return to MO-61.
23.7	6.6	Turn right (east) onto MO-61.
26.0	2.3	Turn left (south) onto MO-51.
28.9	2.9	Turn left (north) onto I-55.

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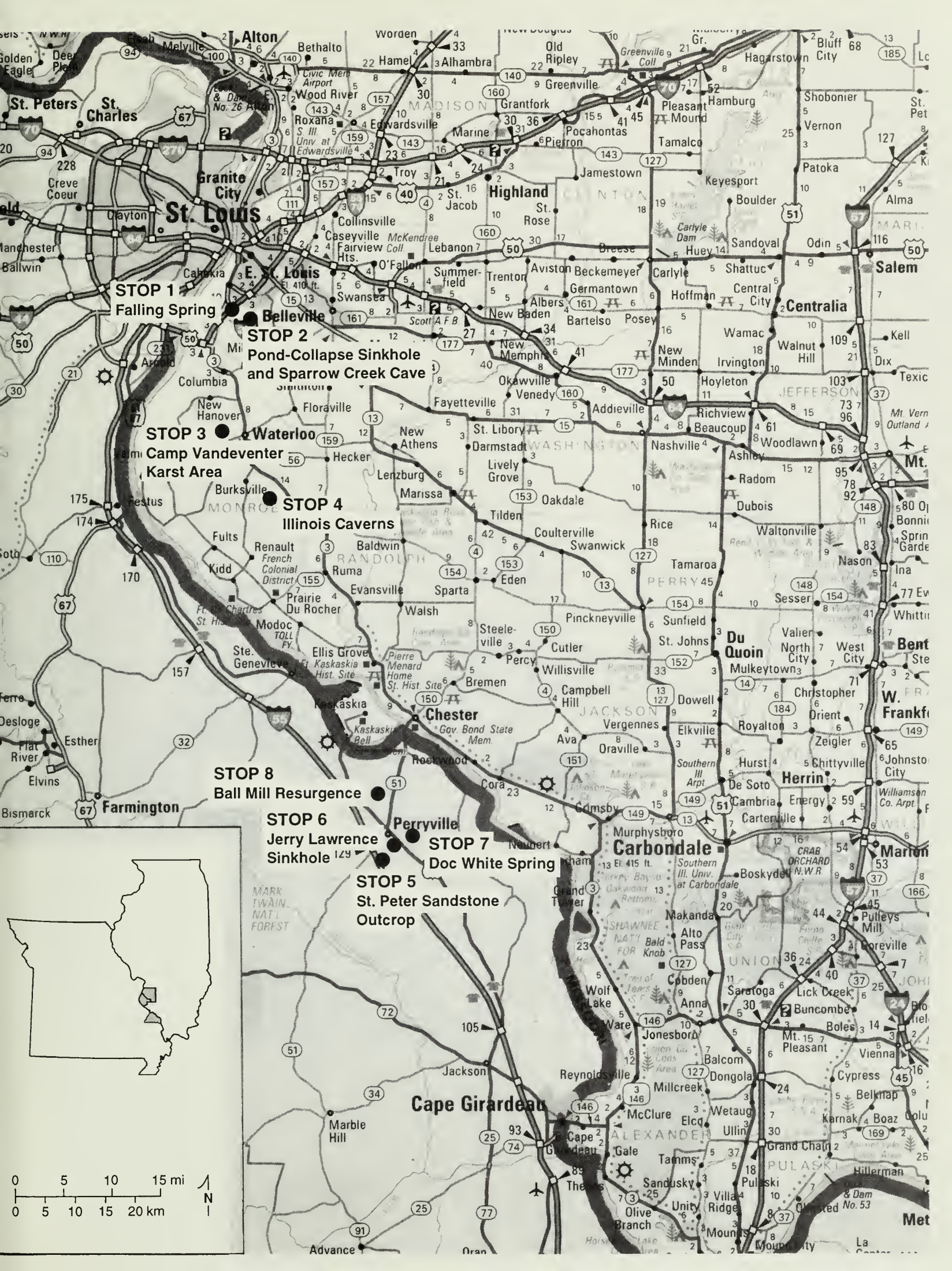
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Field trip route map showing stops (by number) and selected roads and municipalities.



STOP 1
Falling Spring

STOP 2
Pond-Collapse Sinkhole
and Sparrow Creek Cave

STOP 3
Waterloo
Camp Vandeventer
Karst Area

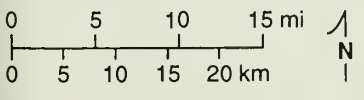
STOP 4
Illinois Caverns

STOP 8
Ball Mill Resurgence

STOP 6
Jerry Lawrence
Sinkhole

STOP 7
Doc White Spring

STOP 5
St. Peter Sandstone
Outcrop



MARK
TWIN
NAT'L
FOREST

Carbondale

Cape Girardeau

Met

